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Ambient air — Measurement of the mass of particulate matter on a filter medium — Beta-ray absorption method

Air ambiant — Mesurage de la masse des matières particulaires sur un milieu filtrant — Méthode par absorption de rayons bêta

Reference number
ISO 10473:2000(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10473 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 3, *Ambient atmospheres*.

Ambient air — Measurement of the mass of particulate matter on a filter medium — Beta-ray absorption method

1 Scope

This International Standard describes a method for the measurement of the mass of particulate matter in ambient air and is based on the absorption of beta rays by the particulate matter.

This method applies to the determination of concentrations ranging from a few micrograms per cubic metre to a few milligrams per cubic metre contained in the atmospheres of urban, rural or industrial areas.

The lower mass detection limit of the method is usually 15 µg to 30 µg of deposited mass per square centimetre of surface area, S, of the filter. This means, for a sampling time t of 3 h and a flowrate q of 1 m³/h, that the concentration detection limit ranges between 5 µg/m³ and 10 µg/m³, computed as follows:

$$\text{Concentration}\left(\mu\text{g}/\text{cm}^2\right)\cdot\frac{S\,(\text{cm}^2)}{q\,(\text{m}^3/\text{h})}\cdot\frac{1}{t\,(\text{h})}$$

Sampling techniques are not included in the scope of this International Standard.

NOTE The concentration of particulate matter is calculated by dividing the mass deposited on a filter tape or individual filter, by the known volume of air sampled. However, concentration is dependent on the sampling technique used, for example, the design of the sampling inlet. Normally, for ambient-air particle sampling, large particles are filtered out by means of a size-selective inlet (for example cascade impactor or cyclone filtration). The particle size limit is defined by the characteristics of the sampling head.

2 Term and definition

For the purposes of this International Standard, the following term and definition applies.

2.1
beta ray
radiation emitted by electrons during the nuclear decay of radioactive elements

NOTE In this International Standard, elements such as ^{147}Pm, ^{14}C or ^{85}Kr may be used.

3 Principle

3.1 Description

A known volume of ambient air is drawn through a filter on which the particulate matter is collected. The total mass of the particulate matter is determined by the measurement of absorption of beta rays. This measurement follows the following empirical absorption law:

$$N = N_0 \cdot \mathrm{e}^{-km} \qquad (1)$$

where

N_0 is the number of incident electrons per unit of time (counts per second);

N is the number of electrons transmitted per unit of time (counts per second) measured after the filter;

k is the coefficient of absorption per unit of mass (cm^2/mg);

m is the areic mass (mg/cm^2) of matter encountered by the beta radiation.

Practically, it is not necessary to determine N_0, and the areic mass of the collected particulate matter is determined as follows.

a) Step one: a measurement is made on a blank filter:

$$N_1 = N_0 \cdot e^{-km_0} \quad (2)$$

where

N_1 is the number of electrons transmitted per unit of time (counts per second) measured after the blank filter;

m_0 is the areic mass (mg/cm^2) of the blank filter.

b) Step two: a measurement is made on the same filter loaded with particulate matter:

$$N_2 = N_0 \cdot e^{-k(m_0 + \Delta m)} \quad (3)$$

where

N_2 is the number of electrons transmitted per unit of time (counts per second) measured after the filter loaded with particulate matter;

Δm is the areic mass (mg/cm^2) of particulate matter collected on the filter.

Combining equations (2) and (3):

$$N_1 = N_2 \cdot e^{+k\,\Delta m} \quad (4)$$

or

$$\Delta m = \frac{1}{k} \ln \frac{[N_1]}{[N_2]} \quad (5)$$

This method of measurement has the following characteristics:

- the empirical exponential law [equation (1)] is valid in the practical working range. There is, however, an upper limit which is directly proportional to the maximum energy of the emission spectrum of the beta source used.

3.2 Limitations

The absorption law (1) can slightly depend on particle density and size for large particles (diameter more than 20 µm). To minimize this effect, large particles are usually filtered out by means of a cascade impactor in the sampling head.

Errors in mass determination can be caused by irregularities in the spatial distribution of the stream of beta electrons and heterogeneous deposits of particulate matter due to a deterioration of the sampling system.

Changes in atmospheric pressure and temperature cause the density of air between the source and the detector to change. This can affect the determination of the mass of particulate matter deposited on the filter. The error can be minimized by keeping the time between the measurement of N_1 and N_2 as short as possible and can be corrected by measuring the atmospheric pressure and temperature, or by use of a dual detection system; in this case, the result of the second measurement (N_2) has to be recorded continuously as mass accumulates over time.

The elemental and chemical composition of atmospheric particulate matter has a small effect on the value of the coefficient of absorption per unit of mass, k.

The effect of radioactivity in particulate matter is negligible for long-lived radioisotopes. However, in locations where low levels of radon and its daughters are present, the response of beta gauges may be affected. The error depends on the type of equipment used.

4 Apparatus

The apparatus should be installed in a room which is controlled for temperature and humidity.

The apparatus may be either automatic with sequential or simultaneous sampling and analysis, consisting of a single assembly, or automatic with separate sampling and analysis, consisting of two sub-assemblies, one for sampling the particulate matter and the other for measuring it.

Schematics of four typical apparatus that allow sequential or simultaneous sampling and analysis, using one or two beta gauges, are shown in Figure 1:

- automatic simultaneous sampler and analyser with 1 beta gauge [see Figure 1 a)];
- automatic sequential sampler and analyser with 2 beta gauges [see Figure 1 b)];
- automatic sequential sampler and analyser with 1 beta gauge [see Figure 1 c)];
- automatic sequential sampler and analyser with 1 beta gauge on separate filters [see Figure 1 d)].

Whichever mode is adopted, the apparatus includes the following main components.

4.1 Apparatus for sequential or simultaneous sampling and analysis

4.1.1 Sample inlet, also called sampling head, generally made of stainless steel, for sampling the particulate matter contained in ambient air. Its characteristics, in conjunction with sampling flowrate, determine the sampling efficiency.

The sampling head should be made from a material resistant to atmospheric corrosion.

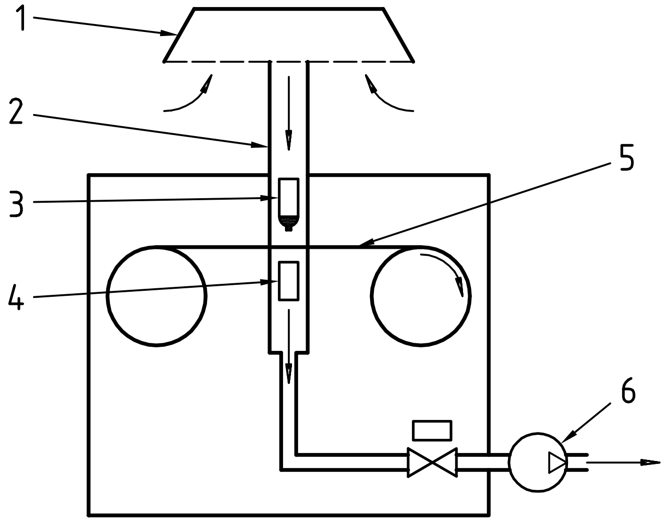
4.1.2 Sample intake tube, preferably straight, perpendicular to the filter, and made of stainless steel, intended to carry the sampled particulate matter to the filter.

It is essential that this tube be designed to prevent losses of particulate matter before reaching the filter. In addition, the tube shall be slightly heated (40 °C to 50 °C) in order to prevent any condensation on the filter. The internal cross-section of the tube and its outlet shall be equal to the exposed area of the filter.

4.1.3 Sealing device to prevent any leak between the lower end of the sample intake tube and the filter, thus preventing any loss of particulate matter and intake of air.

It may consist of a retractable nozzle which stays on the filter during sampling.

A permanent magnet shall not be used as a sealing device.

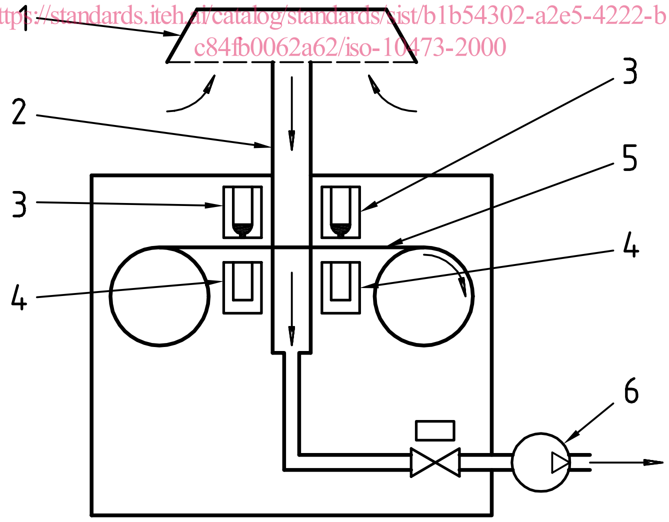


Key

1 Sampling head
2 Sample intake tube
3 Beta gauge emitter unit
4 Beta gauge receiver unit
5 Filter
6 Pump

NOTE The filter is measured before sampling with the pump off to determine the blank. During sampling the beta absorption is recorded. At the end of the sampling period, a new filter portion is then placed in position. In order to minimize the influences described in section 4 a dual detection system may be used.

a) Simultaneous sampler and analyser with one beta gauge

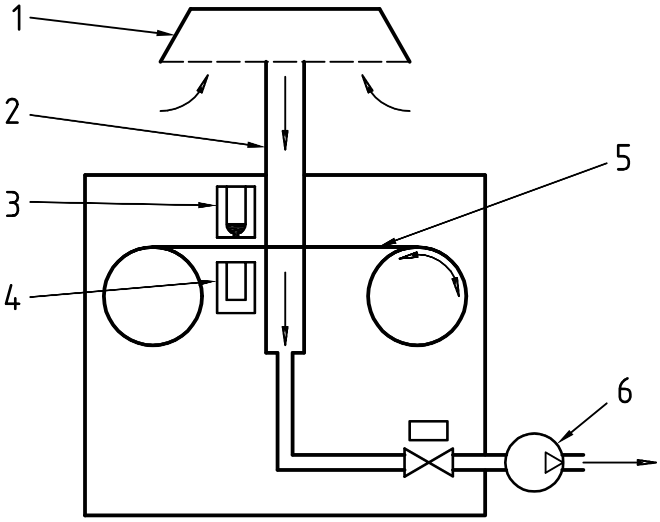


Key

1 Sampling head
2 Sample intake tube
3 Beta gauge emitter unit
4 Beta gauge receiver unit
5 Filter
6 Pump

NOTE The blank filter is measured by the first beta gauge unit. After the blank is determined, the filter passes through the sample collection area. Once sampling is completed, the filter is moved outside of the sampling area, and measured by the second beta gauge unit. The reel moves in only one direction.

b) Sequential sampler and analyser with two beta gauges

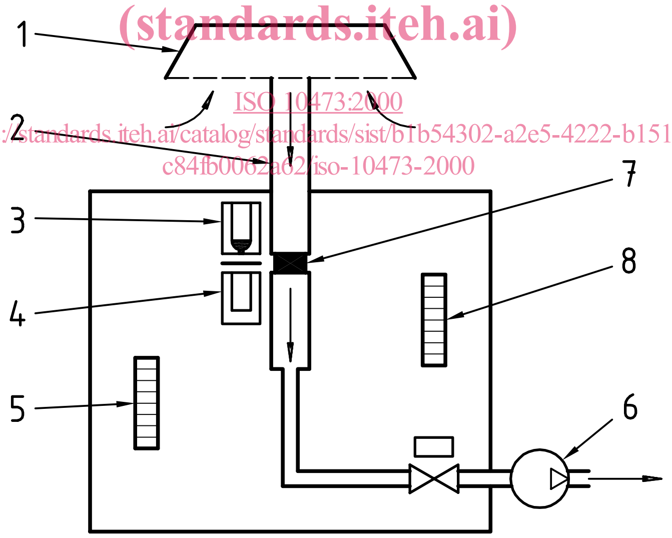


Key

1 Sampling head
2 Sample intake tube
3 Beta gauge emitter unit
4 Beta gauge receiver unit
5 Filter
6 Pump

NOTE The blank value for the filter is measured before sampling. The filter is then placed in the sampling section and after sampling is completed, measured again by the beta gauge. The filter reel moves in both directions.

c) Sequential sampler and analyser with one beta gauge



Key

1 Sampling head
2 Sample intake tube
3 Beta gauge emitter unit
4 Beta gauge receiver unit
5 Blank filters
6 Pump
7 Sampling step
8 Sampled filters

NOTE These instruments do not use reels. Rather, the filters are supported on suitable holders for transportation through the instrument and storage. The filters move back and forth to the beta gauge and to the sampling section in order to provide several measurements on the same filter. The filters can be removed for the analysis of specific compounds. Blanks and used filters are stacked in carriers.

d) Sequential sampler and analyser with one beta gauge on separate filters

Figure 1 — Typical automatic instruments for sequential or simultaneous sampling and analysis